GENERAL ELECTRIC

RE-ENTRY SYSTEMS DIVISION

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13 March 1981

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Alabama 35812

Attention: B. D. Clark, AP 25/B

Subject: NASA Contract NAS8-33952,
Final Report on Change Injection Device Test

Gentlemen:

Forwarded herewith are two (2) copies of the Final Report which documents the results of our Test of Charge Injection Devices. The tests were conducted in accordance with the parameters outlined in the contract and agreements reached with the NASA technical community.

It is our understanding that the submission of this Final Report fulfills our obligations under the terms of this contract.

If you have any questions, please feel free to call.

Very truly yours,

R. F. Brennan
Contract Specialist

RFB/dd

CONTRACT NAS8-33952

TEST OF CHARGE INJECTION DEVICE

PHASE I TECHNICAL REPORT

(October 15, 1980 to March 15, 1981)

A. Grafinger, M. B. Sayles, D. Peters, P. Buckley

March 1981

(NASA-CR-161701) TEST OF CHARGE INJECTION DEVICE, PHASE 1 Final Report, 15 Oct. 1980 - 15 Mar. 1981 (General Electric Co.) 24 p HC A02/MF A01 CSCL 14B

N81-21102

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ABSTRACT

This report describes developmental testing of two GE ST-256, Charge Injection Device (CID) solid state sensor chips.

The ST-256 chip is a 256x256 pixel element array with 65536 picture elements to meet accuracy requirements in projected MSFC stellar sensor applications.

In response to MSFC-RFP, No. 8-1-0-EC-46187, GE-RSD won NASA contract NAS8-33952 and formally initiated tasks 15 October 1980.

A dedicated test area was set up in a specially designed EMI isolated test room.

Selected test and test interface equipment, including calibrated instruments, was assembled and integrated into the facility to maximize efficiency of collecting CID characterization data.

Specifically designed software which enabled Micro-computer interfacing was accomplished with the result that automated data taking was accomplished between the Z-80 and INTEL-MDS (8080 base) Micro-computers.

Two ST-256 were subjected to;

a) Dark Current tests of the chips in a cruciform formed by 8 pixels x 256 (row x column)

b) Light subjected characteristics @ 0.01%, 0.1% and 10% of saturation, also in cruciform coverage.

These data were collected at room temperature.

Thanks to the close and effective cooperation by;

a) Mr. Clyde Jones, MSFC

b) Mr. G. Kollidge, Ball Aerospace Systems Division

c) Mr. G. Michon, GE/CR&DC

successful completion of the CID testing described above was accomplished and the data recorded for future analysis.

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LIST OF FIGURES

I INTRODUCTION

The objective of this program is to obtain device characteristics useful in evaluating CID's as the sensor element in a prospective star tracker application. Specifically, data from an ST-256 was taken to determine representative pixel responsivity and dark current statistics.

The ST-256 Charge Injection Device was designed and manufactured by the General Electric Company Corporate Research and Development Laboratories under contract to Re-entry Systems Division. Previous studies of small CID devices (128 x 128) have indicated that the potential of a larger array in tracker applications is significant. Data exhibiting parametric measurements similar to those taken on the 128 x 128 device have been obtained on this program for the ST-256 CID (256 x 256).

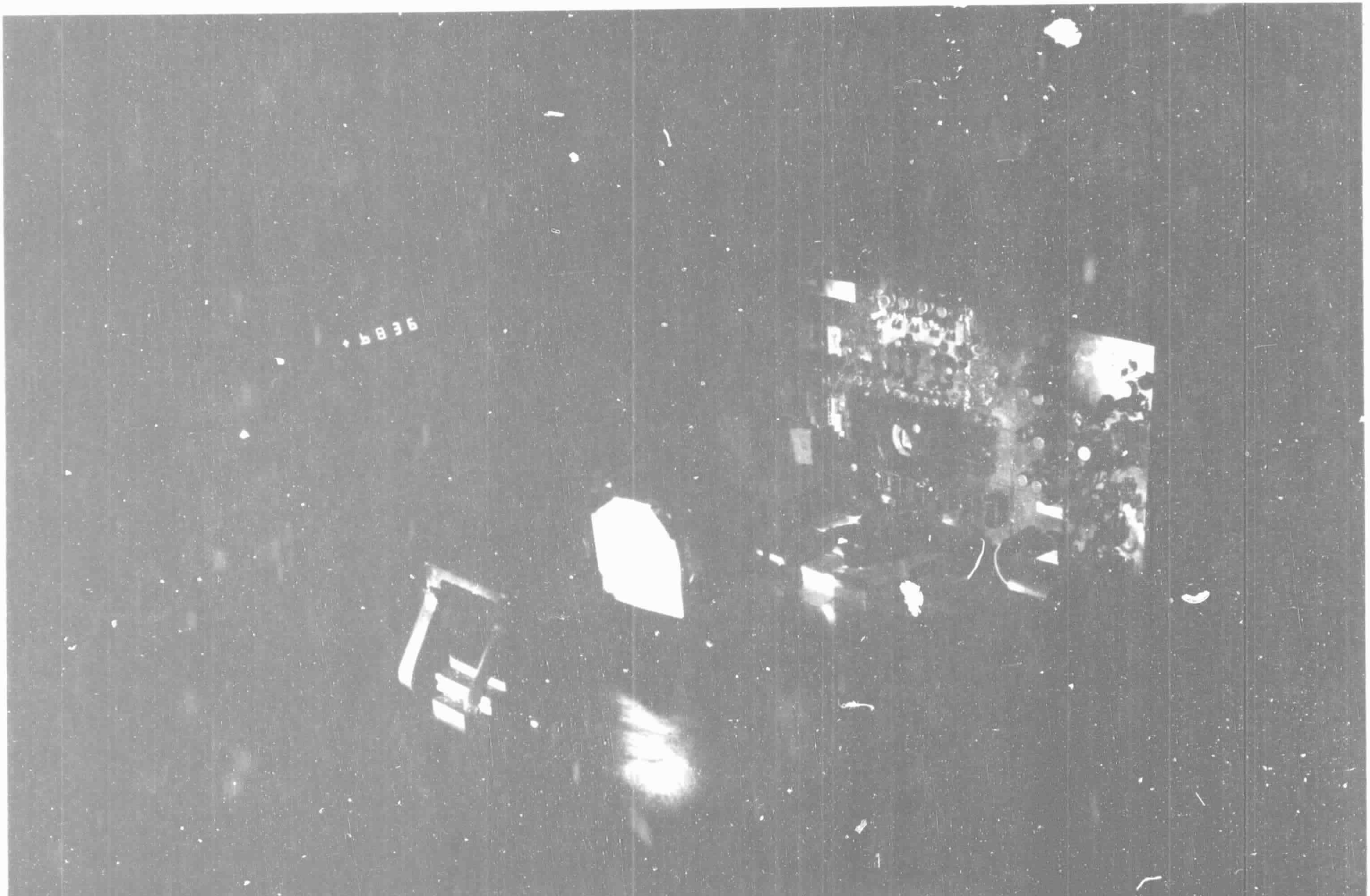
II SYSTEM DESCRIPTION

A. System Overview

The CID test laboratory is a computer controlled automated facility. Two interactive microprocessors, peripherals, and optical bench provide electronic control of the ST-256. Data processing capability is described in the following sections. Figures A, B, C, and D illustrate the components of the test facility. (Fig. A,B - Test Facility Photograph, Fig. C - Computer Block Diagram, Fig. D - Optical Arrangement.)

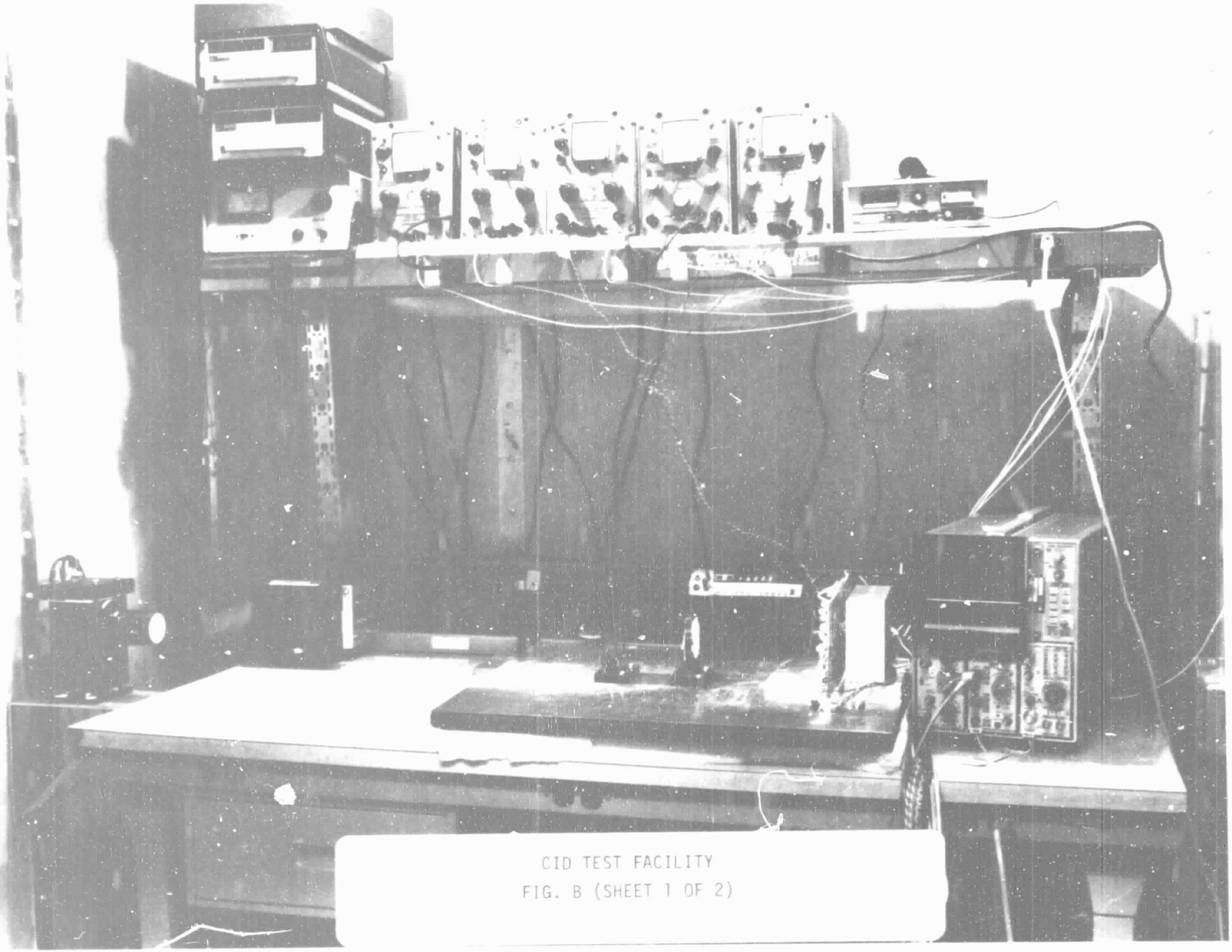
B. ST-256 Camera

The ST-256 is composed of 65,536 pixels: 256 rows and 256 columns. In addition, a dummy compensation row provides differential cancellation of column drive interference. Array layout is shown in Figure E, ST-256 Array Layout. Array parameters, circuit description and timing waveforms are similar to those reported in section

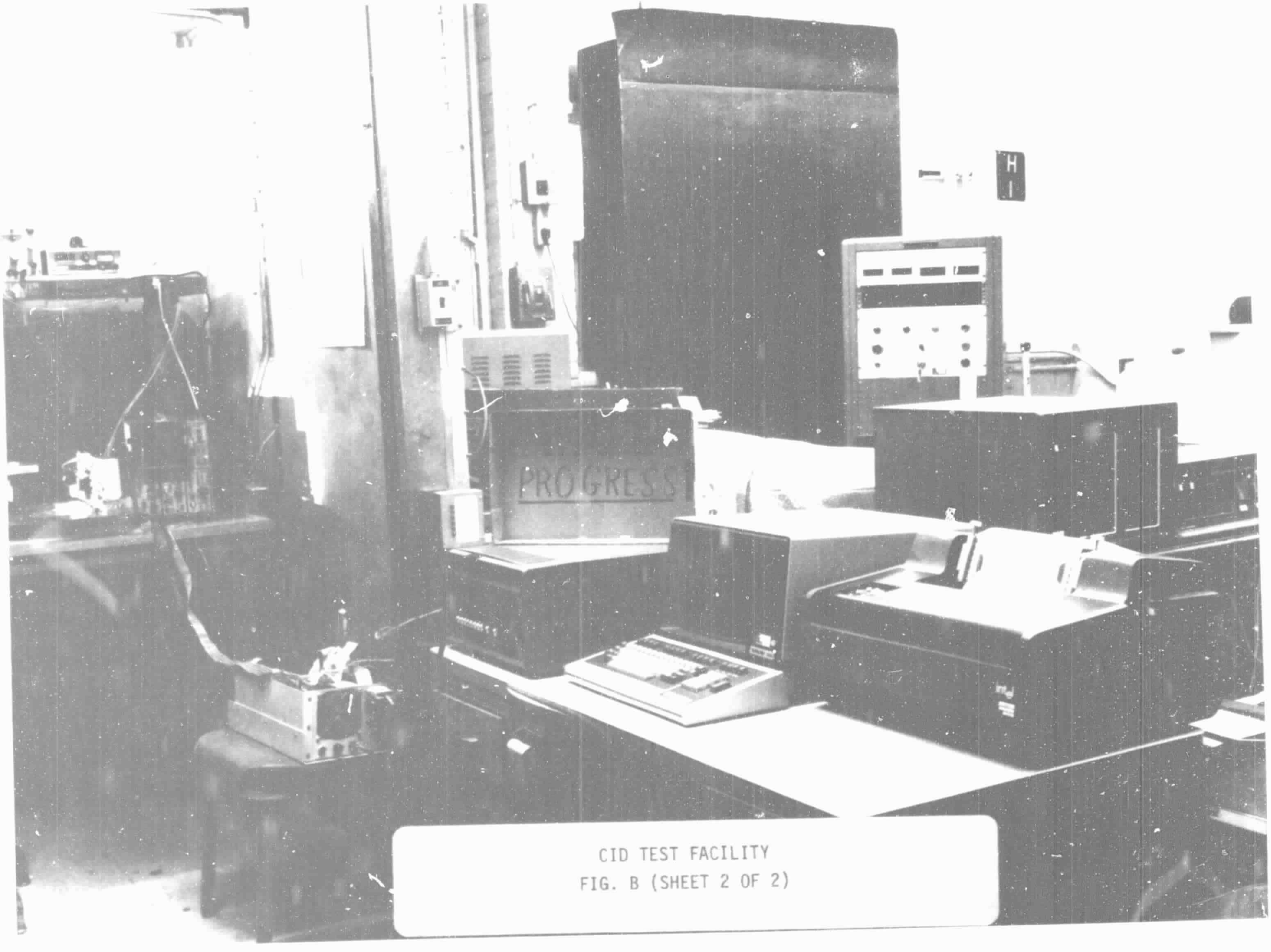


ST-256 CAMERA

FIG. A

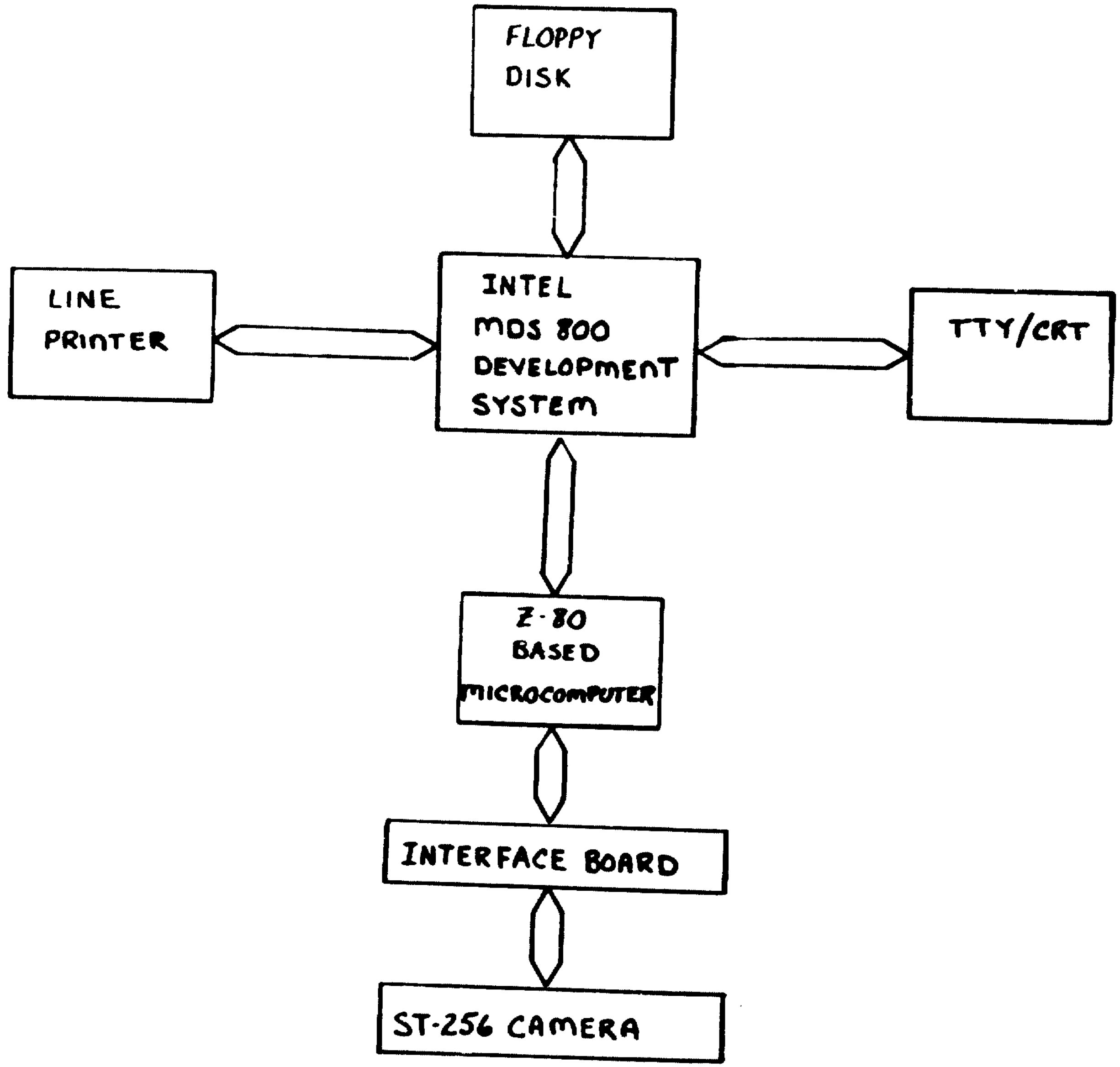


CID TEST FACILITY
FIG. B (SHEET 1 OF 2)



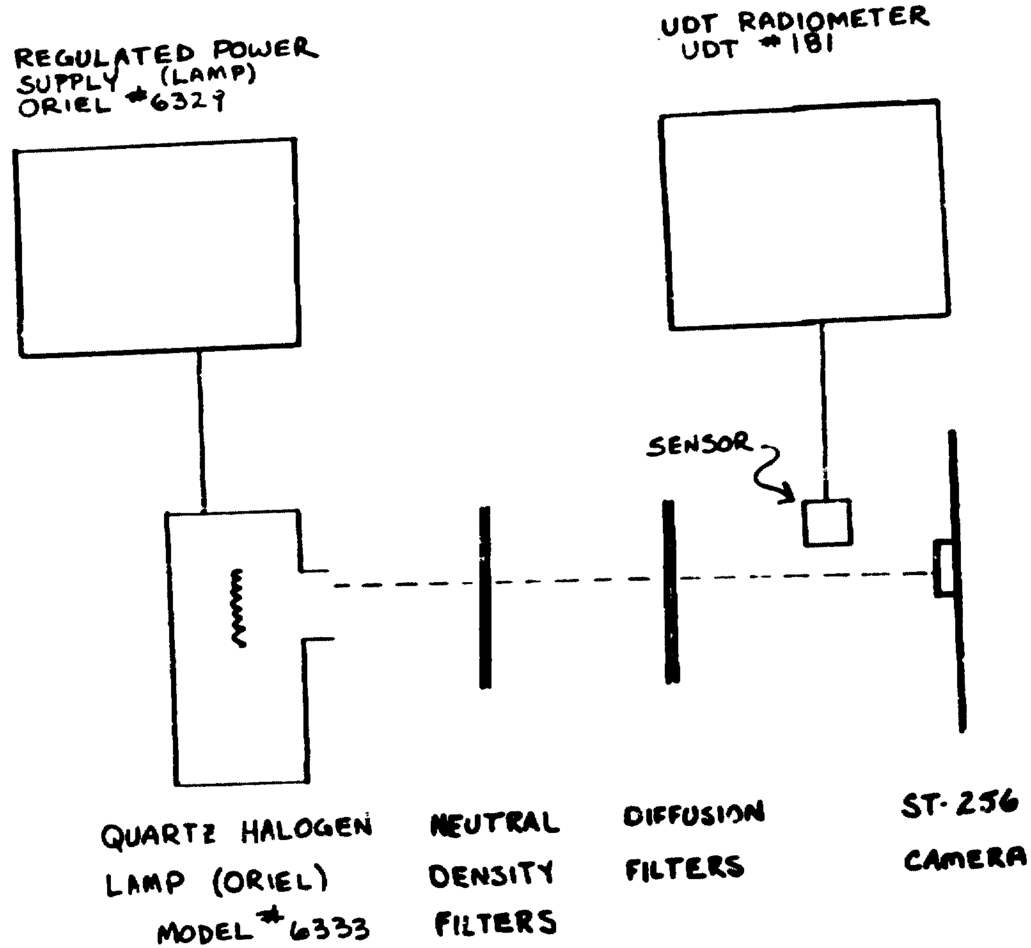
CID TEST FACILITY

FIG. B (SHEET 2 OF 2)



CID TEST COMPUTER BLOCK DIAGRAM

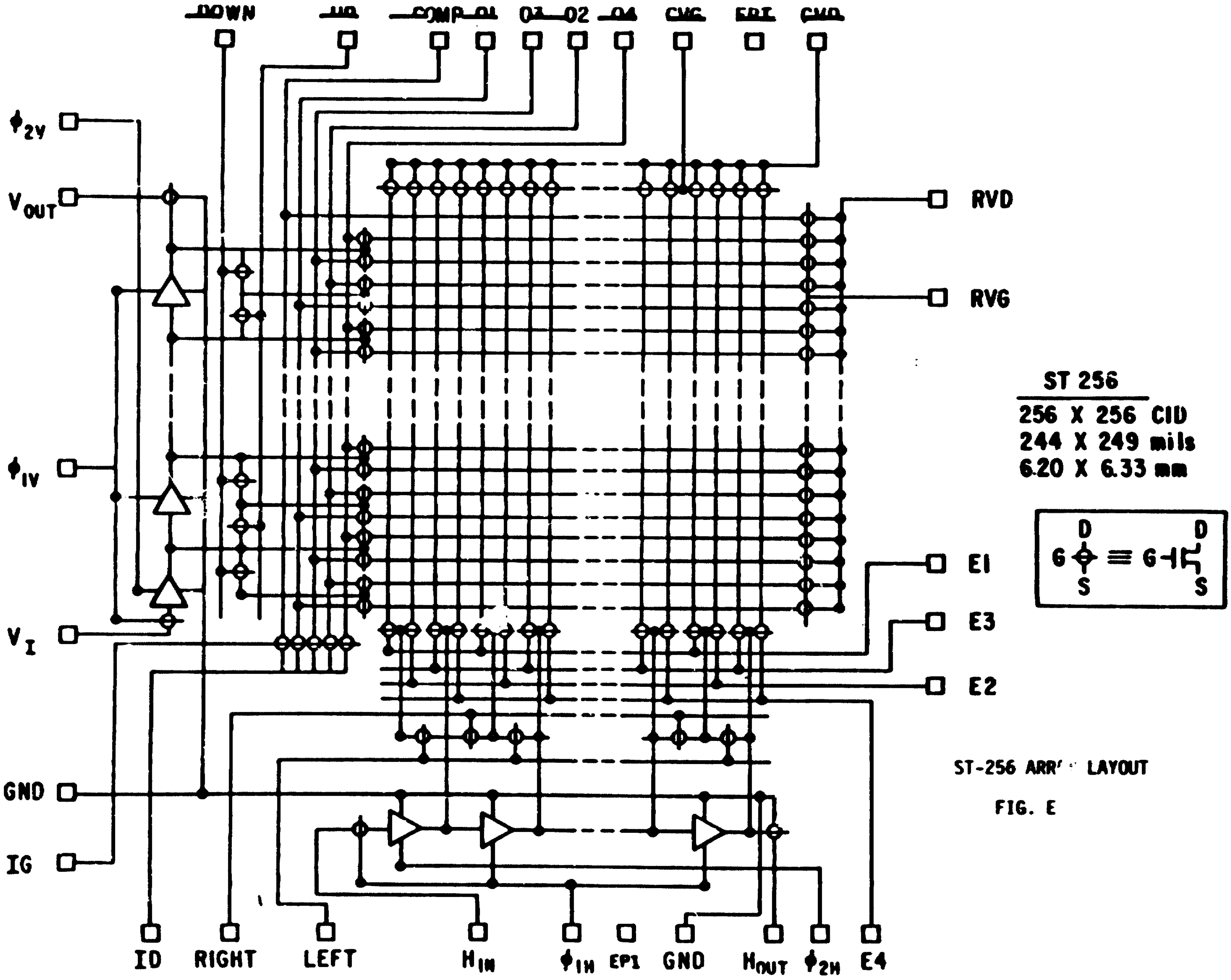
FIG. C



CID TEST

OPTICAL ARRANGEMENT

FIG. D



ST-256 ARR[illegible] LAYOUT

FIG. E

3.0 of Reference #1 Final Technical Report, Contract NAS8-32801, SRD-78-171. The ST-256 chip is mounted on a thermo-electric cooler which is enclosed within a sealed header in a dry nitrogen environment. The header assembly plugs into a socket on the camera board.

C. Test Fixture Description

A Zilog Z-80 based microcomputer provides timing sequences for device control. A custom interface board containing optical isolators and A/D conversion accomplishes the digital interface between the Z-80 and the camera electronics. An Intel 8080 based microcomputer performs operator interface, test control, data reduction, and permanent storage functions. Processed and formatted data is stored on floppy discs. Computer configuration is shown in Figure C, CID Test Computer Block Diagram.

Uniform irradiance of CID array is provided by a regulated quartz halogen lamp source. The power supply is adjusted to a nominal 3320 degree K color temperature. Light intensity is adjusted using neutral density filters, and intensity is measured by substitutionally positioning a radiometer sensor in the focal plane of the CID. Figure D, CID Test Optical Arrangement illustrates the optical set-up.

D. Software Fixture Description

Modular software programs are used to control test sequencing and data processing. Programs are stored and executed in the Z-80 microcomputer, and the MDS-800 microcomputer. Within EPROM memory in the Z-80 resides the firmware that controls signal sequencing to drive and sample the ST-256. This is a core program that performs addressing, and correlated double sampling using the non-destructive double read method described in Section 3.1 of Reference #1, and illustrated in Figure F, Non-Destructive Double Read Technique. Collected data is temporarily stored in RAM on the Z-80 microcomputer, and transferred to the MDS-800 for processing. The core program in the Z-80 can be modified and reinstalled to accomplish variations in

NON DESTRUCTIVE DOUBLE READ TECHNIQUE

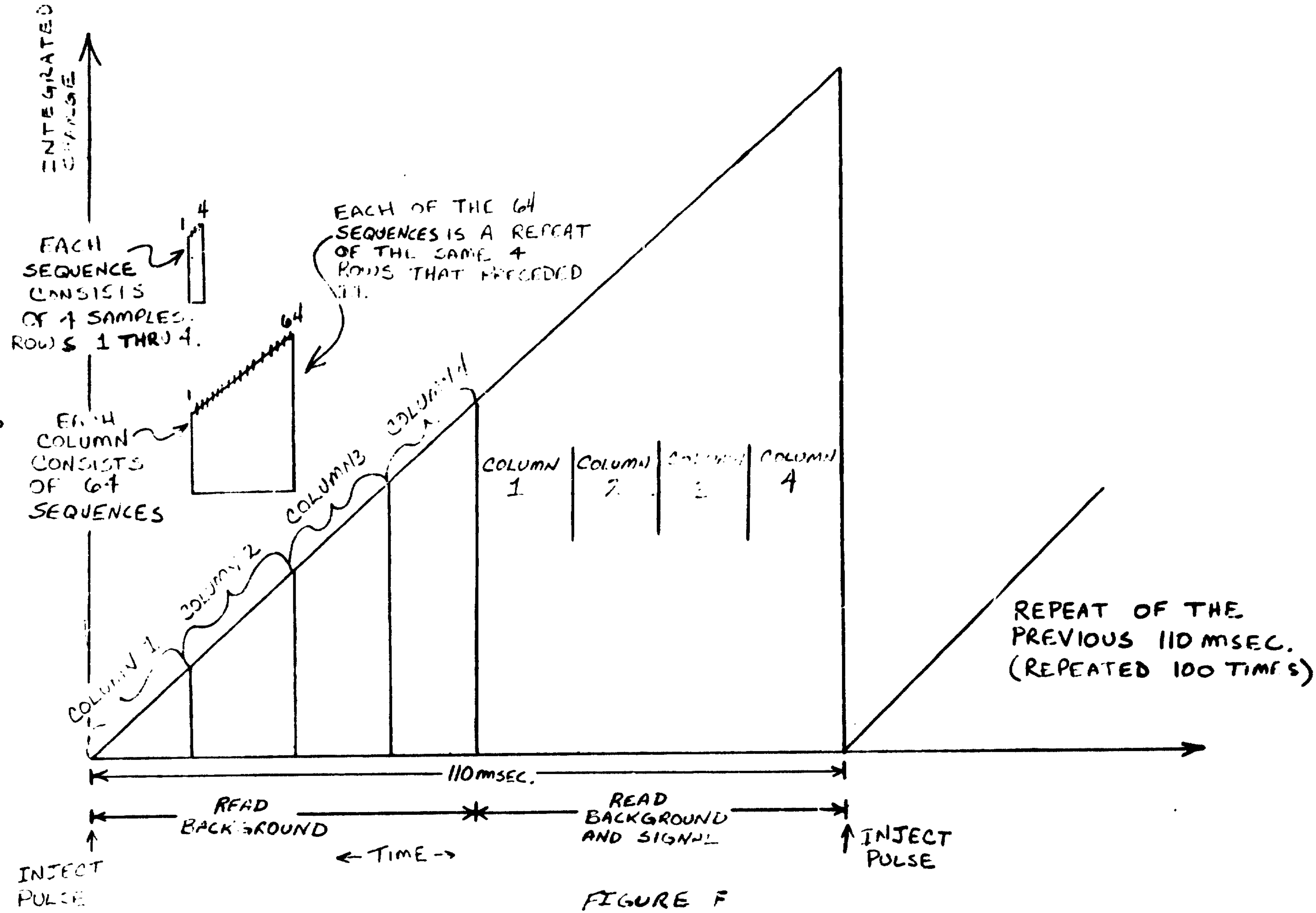


FIGURE F

timing and readout techniques. Operator interface, overall test control, and data processing is performed by Fortran programs executed on the MDS-800 system. A parallel interface having software controlled communication protocols links the Z-80 and MDS-800 together. The Fortran programs are broken into functional entities which provide flexibility and efficient maintenance as shown by the block diagram in Figure G, CID Test Software Components.

III CALIBRATION AND SET-UP

Equipment calibration and laboratory set-up is accomplished in three phases: reduction of laboratory induced noise, adjustment of ST-256 Camera based electronics, determination of saturation levels.

Laboratory induced noise is effectively minimized by point grounding all power supplies, and by verifying common ground of the ST-256 board, header casing, heat sink, and CID substrate.

Adjustment of the ST-256 Camera Electronics is as follows. A-C balancing is done by observing the scope measurement of the NE 5534 operational amplifier outputs with respect to ground. Adjust the respective 3 pF trim capacitors on the back of the board to minimize the signal modulation of each channel. D-C balancing requires measuring, with a voltmeter, the inputs to the NE 5534 operational amplifiers. Adjust the respective 1K trim pot in the pre-amp stage to produce -4.3VDC at the inputs to each op-amp. The final circuit adjustment is to trim the 10K bias pot in the restore circuit to produce a signal level of 0.5V at the output of the sample and hol .

Saturation is defined as the light level that results in a sample and hold output of 5.0 volts. Light level is measured by positioning the radiometer detection head in the focal plane of the CID. Percentages of saturation are accomplished by using neutral density filters.

CID TEST SOFTWARE COMPONENTS

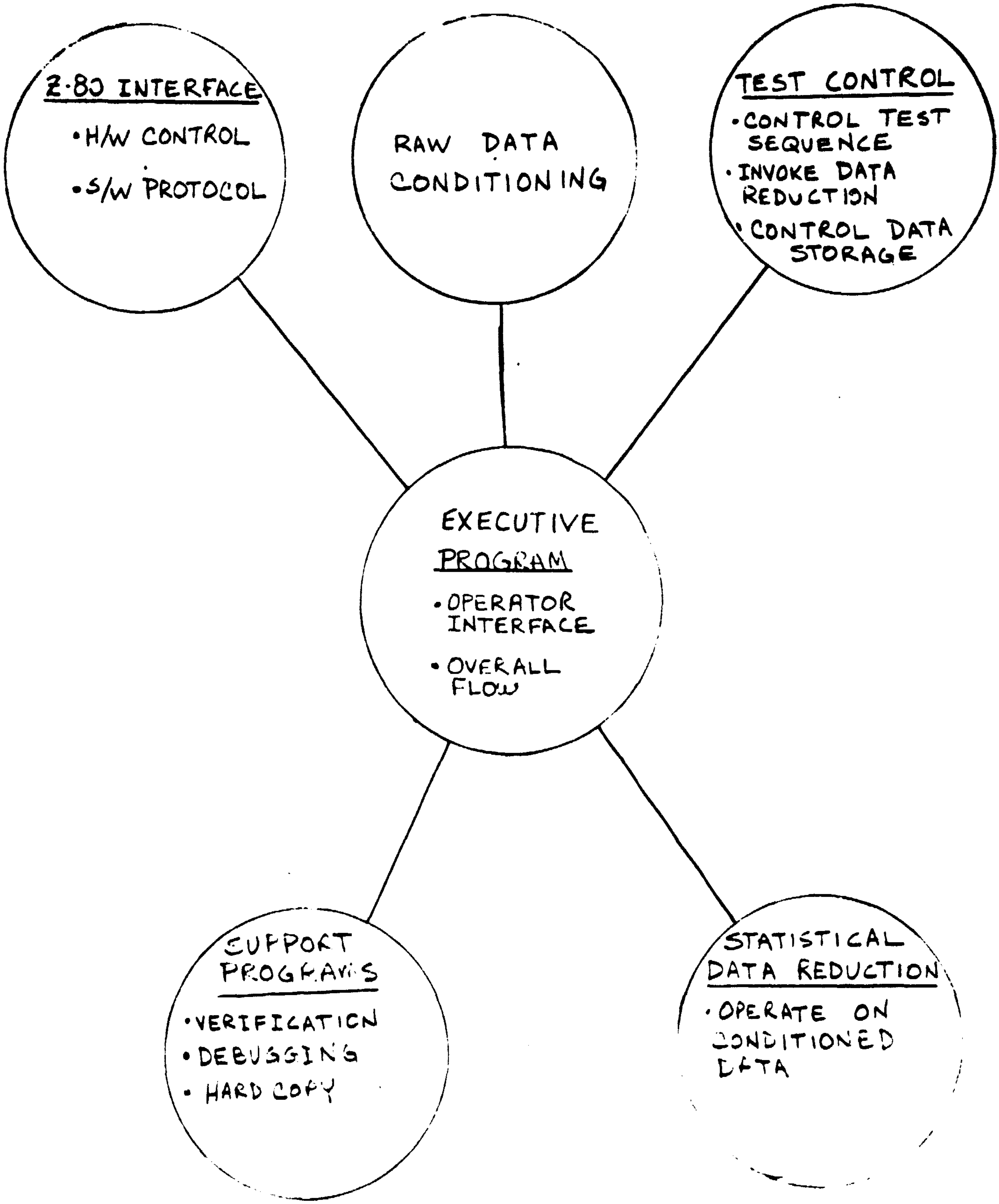


FIGURE 6

IV DATA COLLECTION

A field of pixels representative of the array is used for all of the tests performed on this program. The pixels tested form a cruciform shape as shown in Fiqure H. Data collection is done as described below, and illustrated in Figure H, Diagram of Pixels Tested.

Pixel addressing is accomplished by selecting, in Cartesian coordinates, the column number and row number of the desired pixel. This address enables a 4 x 4 block of pixels surrounding the specified address. Charge is cleared from all pixels, a new integration cycle and sampling beings.

The Z-80 microcomputer collects data and provides the timing waveforms. A 12-bit A/D converter module with an 8-channel differential-input multiplexer, buffer amplifier, and sample-and-hold circuit is used at its maximum throughput rate of 100 KHz. Each column is selected, one at a time. Each of the 4 pixels in the column are sampled simultaneously. After the sample is taken and held, the computer reads the four rows individually by sequentially updating the miltiplexer channel, making conversions, and reading the A/D.

The computer stores an 18-bit sum of sixty-four 12-bit "background" readings for each pixel in the 4 x 4 group. Next, a "signal + background" reading is then taken. The "background" readings in storage are subtracted from "signal + background" and the 18-bit difference is stored in the proper location in memory. We have determined that the A to D converter quantization noise is insignificant as long as the RMS value of the noise to be measured is greater than, or equal to, the value of one least significant bit of the converter. For our setup, this LSB corresponded to 200 carriers. Another advantage of averaging 64 reading is that the noise on the average is $(64)^{1/2}$ or 8 times less than the noise on the individual readings. As a result, we can obtain the precision of a 15-bit A/D converter while using only

CRUCIFORM SHAPE

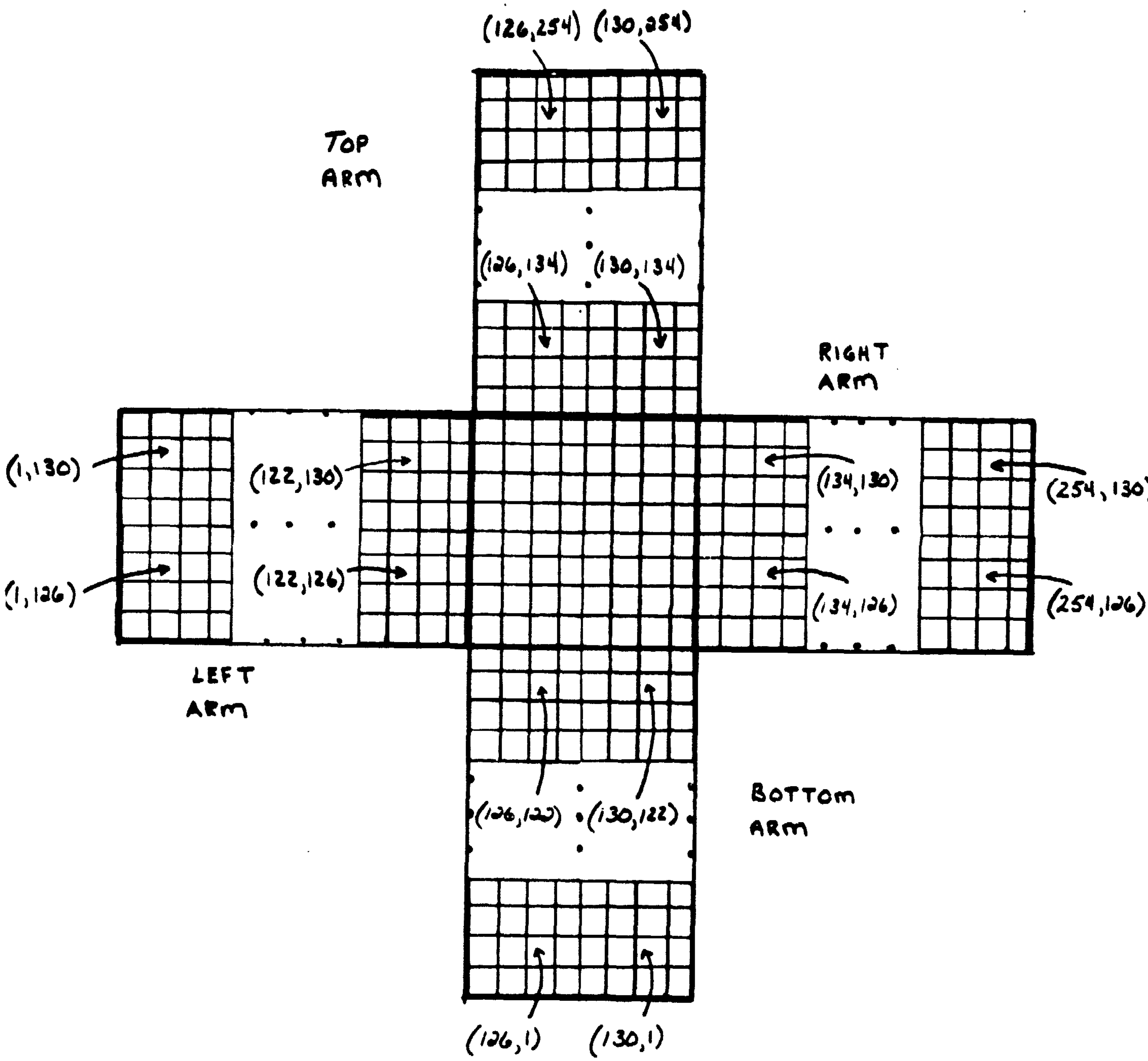


DIAGRAM OF
PIXELS TESTED

FIG H

12 bits. The difference taking adds a factor of $(2)^{\frac{1}{2}}$ to the noise, since the noise adds incoherently. Thus one can measure noise levels as low as 35 carriers RMS with no significant quantization noise contribution. Samples were collected and stored as described above. To perform statistical analysis, a 4 x 4 block is read 100 times, resulting in 100 sums for each of the 16 pixels. These numbers are then transferred to the MDS-800 computer for processing while the Z-80 selects and samples the next block of pixels.

Sample mean and sample standard deviations are calculated for each pixel. The mean and standard deviations are stored sequentially on floppy disc files. Examination of the data under each condition was performed to verify that it is meaningful. File formats are illustrated in Figure I, Data File Format.

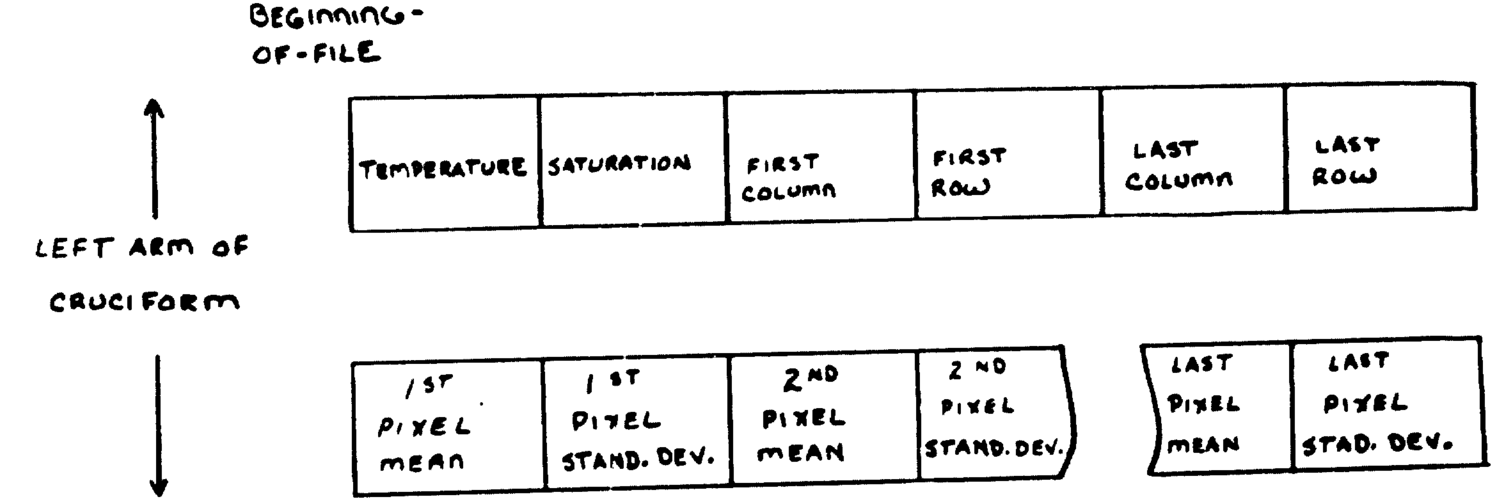
V RESULTS

Each part of the CID characterization tests produced engineering insight necessary to further advance CID technology toward star tracker applications. The results described below indicate chronologically the accomplishments of this program.

A. Calibration Results

Noise

Grounding is critical to minimizing noise levels in the CID laboratory. Care in grounding as described earlier in this report was found to be necessary to attain an acceptable noise level. The initial CID header assembly under test was replaced because of inadequate common ground between the substrate, header casing, and the heat sink. After obtaining a new CID, and carefully implementing a laboratory ground scheme, the level of grassy noise appearing on each individual sample and hold output reading was reduced to 10 mv peak to peak. Initial levels were as high as 200 mv. Peak to peak variations between each of the 64 readings is about 75 mv as read from a scope. Statistical levels are recorded in the data.



- FORMAT REPEATS FOR:
  - TOP ARM
  - RIGHT ARM
  - BOTTOM ARM
  - CENTER BLOCK
- END-OF-FILE FOLLOWS FINAL ENTRY OF CENTER BLOCK

(1) There is one file for each test condition.

(2) Data is stored in the same sequence that it is taken. Row address is incremented nested within the column increment:

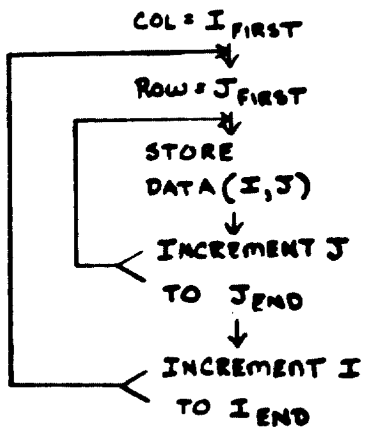


FIG I DATA FILE FORMAT

Temperature

Tests at low temperature indicate that noisture levels within the CID header create device failures caused by condensation at low temperatures. As a result of this difficulty, low temperature tests were deferred.

B. Data Results

Two ST-256 CID devices were tested at $20^{o}C$ under light levels of 10%, 0.1%, 0.01% saturation, and in darkness. The saturation level was established at 0.95 microwatts/cm^2 as measured by the radiometric sensor. Two test runs under each condition were performed for each chip. This provides 2 complete sets of results for each of the 2 devices. A separate data file is used to store the results of each test condition. Repetative runs of a test condition are stored sequentially in the same file. Figure J, Data File Reference Table, lists the data files. Examination of the data using print-outs as shown in Figures K, Partial Data File Dump, and L, Typical Noise Statistics Print-Out, is performed to verify the validity of the test runs.

LIGHT LEVEL (mW/cm^2)	TEMPERATURE (^oC)	CHIP NUMBER	DISK NAME	FILE NAME
0	20	1	C1DRK.20	C1DRK.20
0.01	20	1	C1PT01.20	C1PT01.20
0.1	20	1	C1PT1.20	C1PT1.20
10.0	20	1	C1TEN.20	C1TEN.20
0	20	2	C2DRK.20	C2DRK.20
0.01	20	2	C2PT01.20	C2PT01.20
0.1	20	2	C2PT1.20	C2PT1.20
10.0	20	2	C2TEN.20	C2TEN.20

DATA FILE REFERENCE TABLE

FIG. J

HEADER: TEMPERATURE, SATURATION, 1st COL, 1st ROW, LAST COL, LAST ROW

DATA: MEAN,STANDARD DEVIATION

20 10 1 126 122 122

9362.566	79.564
9395.526	87.432
9325.762	96.761
9207.694	75.269
5081.318	80.857
5085.076	87.012
5077.303	85.338
5068.381	75.463
5094.916	79.514
5089.092	80.329
5083.470	77.515
5065.025	81.447
4679.174	100.025
4687.264	97.054
4674.728	101.168
4666.438	104.962
9538.038	106.696
9581.440	104.035
9523.150	104.327
9476.240	117.062
5947.296	112.992
5960.090	111.416
5950.395	116.023
5931.261	109.051
5239.906	122.697
5254.357	125.369
5224.501	133.076
5220.421	126.539
4667.011	122.279
4673.300	126.959
4644.063	128.479
4643.008	117.894
6060.721	118.462
6100.938	107.429
6047.410	109.441
6019.958	112.992
5612.387	120.940
5627.505	116.241
5626.415	109.465
5616.005	118.552
5196.240	126.329
5203.066	110.589
5183.905	113.274
5166.636	120.212
5199.768	113.649
5203.927	122.092
5183.244	136.400
5177.049	125.155
6261.523	109.998
6298.642	130.454
6251.253	137.924
6224.747	123.022
5821.422	115.334
5838.089	113.168
5800.711	126.108
5814.365	123.852
5655.473	125.144
5639.840	108.770

PARTIAL

DATA FILE DUMP

FIG. K

CID NOISE STATISTICS

SINGLE PIXEL NOISE

TEMP	SAT	COL	ROW
20C	0.1%	127	127

AVG MEAN	AVG NOISE
1448.95	63.44

MEAN (CARRIERS)

1998.81	1343.11	1210.46	1109.81
2053.86	1360.69	1221.39	1186.08
2026.98	1357.68	1237.46	1169.93
2060.34	1356.59	1233.04	1176.10

STANDARD DEVIATION (CARRIERS)

67.13	65.67	62.39	66.95
72.34	65.09	62.57	69.27
64.61	61.65	51.91	60.35
62.49	54.55	64.20	63.81

CID NOISE STATISTICS

SINGLE PIXEL NOISE

TEMP	SAT	COL	ROW
20C	.01%	127	127

AVG MEAN	AVG NOISE
1409.65	64.49

MEAN (CARRIERS)

1960.37	1313.13	1174.12	1137.46
2014.59	1315.00	1181.89	1131.29
2068.60	1311.21	1183.44	1131.26
2027.24	1302.11	1183.04	1118.81

STANDARD DEVIATION (CARRIERS)

70.25	63.65	64.57	59.75
71.00	63.37	65.76	62.67
66.47	67.41	65.93	62.29
62.87	67.10	63.00	54.00

TYPICAL NOISE STATISTICS PRINT-OUT

FIG. L (SHEET 1 OF 2)

CID NOISE STATISTICS

SINGLE PIXEL NOISE

TEMP	SAT	COL	ROW
20C	10%	127	127

AVG MEAN	AVG NOISE
5764.93	74.40

MEAN (CARRIERS)

6720.24	5673.63	5400.52	5247.50
6665.65	5662.70	5471.35	5239.44
6630.31	5650.37	5475.73	5239.12
6682.32	5668.30	5470.16	5251.57

STANDARD DEVIATION (CARRIERS)

67.03	76.30	74.02	85.14
68.61	75.89	79.13	81.94
70.01	71.61	79.06	76.70
72.39	65.40	73.95	73.57

CID NOISE STATISTICS

SINGLE PIXEL NOISE

TEMP	SAT	COL	ROW
20C	0%	127	127

AVG MEAN	AVG NOISE
1371.21	65.31

MEAN (CARRIERS)

2025.29	1276.01	1135.36	1034.14
1963.47	1270.02	1145.69	1006.40
1945.66	1260.23	1149.56	1063.96
1980.31	1278.16	1158.60	1085.62

STANDARD DEVIATION (CARRIERS)

66.05	63.62	60.05	60.02
60.97	70.00	61.14	58.58
67.09	60.63	70.71	60.10
66.35	64.01	64.59	63.02

TYPICAL NOISE STATISTICS PRINT-OUT

FIG. L (SHEET 2 OF 2)